EXPERMENTAL STUDY OF THE POLLUTANTS EMISSION FOR A SPARK IGNITION ENGINE FUELED WITH GASOLINE AND BIO-ETHANOL BLENDS

دراسة عملية لانبعاث الملوثات لمحرك اشعال بالشرارة يعمل بوقود خلائط البنزين والايثانول الحيوي

Prof. Dr.
Haroun A.K. Shahad
Ministry of Higher Education
&Scientific Research
Republic of Iraq - University of Babylon

Assistant Lect
Saad Kadhim Wabdan
Governorate Public and Local Administration
Planning & Follow-Up Department
Republic of Iraq - Al Muthanna

Abstract:

The gasoline is fossil fuel, which is limited in reservoirs and produces pollutions during combustion. This causes varieties of study in search of alternative fuel for SI engine. Bioethanol has been used as an alternative fuel or fuel additive in spark ignition (SI) engines for years; because ethanol fuel is, higher combustion velocity could help increase the combustion efficiency and minimize the emission pollution .This study is an experimental investigation of the effect of bioethanol addition to gasoline on the exhaust emissions in terms (carbon dioxide CO_2, carbon monoxide CO, unburnt hydrocarbons UHC and nitric oxide NO_X) of a spark ignition engine of a spark ignition engine. The tests were conducted at controlled throttle variable speed condition over the range of 1200 to 2000 rpm with intervals 400 rpm with compression ratios CR= 7,8,10, and 11 using pure gasoline and bioethanol gasoline blends. Ethanol energy ratio (EER) was set to be (5%, 10%, and 15%). The blending of gasoline and bioethanol is done on energy replacement basic. The bioethanol used is produced from Iraqi date crop (zehdi).At each of the three designated engine speeds, the torque was set as (0, 3, 7, 10, 14) N.m. It is found that ethanol blending reduces carbon monoxide and unburnt hydrocarbon in the exhaust gases by about 45% & 40.15% respectively and increases the nitric oxide emissions and carbon dioxide in the exhaust gases by about 16.18% & 7.5% respectively.

It is found also that the increase of load and speed causes increasing in pollutants concentration (CO_2, and, NO_x), while decrease in the (CO, HC). Finally, the result show that increasing the compression ratio causes the exhaust emissions namely (CO_2 and NO_X) to decrease while the (CO and HC) to increase.

1-1 Introduction

In recent years, given the dramatically increasing demand of energy, public concern has steadily increased regarding a possible shortage of fossil fuel resources, energy safety policies, and environmental pollution regulations. The degradation of the global environment and the foreseeable future depletion of worldwide fossil fuel reserves have been the driving force to searching alternative fuels that are sustainable and environmental friendly. Ethanol fuel is one of the renewable fuels for addressing these issues. The potential of ethanol fuel in improving the performance of internal combustion engines has been extensively investigated. **[1, 2]**. In 2005, the Australian Government's Biofuels Taskforce reported that the environmental and human health impact of using ethanol as a biofuel was a major issue requiring resolution in order to guide national policy measures aimed at reducing greenhouse gas emissions. Because of the excellent miscibility of bioethanol with common gasoline, it can be used as an additive to partially replace the gasoline as an automotive fuel. Such mixtures are normally named after the amount or percentage of ethanol contained in the blended fuel [**3**].

1-2 LITERATURE REVIEW

Bioethanol is renewable, biodegradable, and environmentally friendly alternative fuel, because it can be produced from agricultural products and scrapped resources. The road transport network accounts for 23% of total greenhouse gas and through the use of bioethanol fuel, these emissions will be reduced. Because of these numerous benefits, bioethanol, and ethanol–gasoline blends are widely used and investigated as alternative fuels in automotive vehicle [**4-6**]. The effects of ethanol addition to gasoline on a spark ignition engine performance and exhaust emissions were investigated experimentally and theoretically. It was found that the ethanol addition to gasoline has caused leaner operation and improved the combustion process. The potential of ethanol fuel in reducing the emission pollution of internal combustion engines has been extensively investigated; **Liao S. et. al.,2005 [7]** performed experimental study in a closed combustion chamber to investigate combustion characteristics and emission pollution of ethanol-gasoline blends at low temperature, which is related to the cold-start operation of engines fueled with ethanol-gasoline. The exhaust emissions are purposely measured in terms of unburned hydrocarbon (UHC), carbon monoxide (CO), and oxides of nitrogen (NO_x) emissions. It was confirmed that the emissions of HC during rich combustion at relatively low temperature increased with increasing the addition of ethanol into gasoline. **Najafi G., et. al. ,2009 [8]** analyzed experimentally the pollutant emissions of a four-stroke SI engine operating on ethanol–gasoline blends of 0%, 5%, 10%, 15% and 20% with the aid of artificial neural network (ANN). theoretically. The concentrations of CO and HC emissions in the exhaust pipe were measured and found to be decreased when ethanol blends were increased. This was due to the high oxygen percentage in the ethanol. In contrast, the concentration of $CO_2$and NO_x was found to be increased when ethanol is introduced. **Najafi G., et.al. , 2009 [9].** Evaluated potato waste bioethanol as an alternative fuel for gasoline engines. The pollutant emissions of a four stroke SI engine operating on ethanol-gasoline blends has been investigated experimentally and theoretically**.** Experiments were performed with the blends containing 5, 10, 15 and 20 vol% ethanol**.** Exhaust gas emissions were measured and analyzed for unburned hydrocarbons (UHC), carbon dioxide (CO_2), carbon monoxide (CO), Oxygen (O_2) and oxide of nitrogen NO_x at engine speeds ranging from 1000 to 5000 rpm. The concentration of CO and UHC emissions in the exhaust pipe were found to be decreased when ethanol blends were introduced. The concentration of CO_2 and NO_x was found to be increased when ethanol is introduced. Results obtained from both theoretical and experimental studies were compared. The simulation results have been validated against data from experiments and a good agreement was noticed between the trends in the predicted and experimented results. **Seshaiah N. ,2010 [10]** performed tests on a variable compression ratio spark ignition designed to run on pure gasoline, LPG (Isobutene), and gasoline blended with ethanol 10%, 15%, 25% and 35% by volume. In addition, the gasoline was mixed with kerosene at 15%, 25% and 35% by volume without any engine modifications. CO and CO_2 emissions had been also compared for all tested fuels. It was observed that the LPG is a promising fuel at all loads, which produced lesser carbon monoxide emission compared with other fuels tested. Ethanol was used as a fuel additive to the mineral gasoline; (up to 30% by volume) without any engine modification and no efficiency lose was noticed. **Ozsezen A.N. and Canakci M.,2011 [11]** studied the exhaust emissions of a vehicle fueled with low content alcohol (ethanol and methanol) blends and pure gasoline. The vehicle tests were performed at wide-open throttle by using an eddy current chassis dynamometer with vehicle speeds of (40 km/ h, 60km/h, 80km/h and 100 km/ h). The test results obtained with the use of alcohol gasoline blends (5 and 10 percent alcohol by volume) were compared to pure gasoline test results. The test results indicated that when the vehicle was fueled with alcohol gasoline blends the exhaust emission results, a stable trend was not seen, especially for CO emission. But, on average, alcohol gasoline blends exhibited decreasing HC emissions. In 100 km/ h vehicle speed test, the alcohol gasoline blends provided lower NO_x emission values compared to pure gasoline. At all vehicle speeds, minimum CO_2 emission was obtained when 5% methanol was added in gasoline. **Sales L. C. M. and Sodré J. R. ,2012 [12]** presented the exhaust emission levels from a flexible fuel engine with heated intake air and fuel during cold start operation. Electric resistances provided heating of intake air and fuel**.** The exhaust emissions from the engine equipped with heated intake air and ethanol injector was compared with the levels obtained from the conventional cold start system that uses gasoline as auxiliary fuel. The use of heated intake air and ethanol in substitution to the conventional system that introduces gasoline in the intake pipe to help cold start of a flexible fuel engine fuelled with hydrous ethanol ((ethanol with 6.8% water mass content)) produced significant reductions on raw exhaust HC and CO emissions, especially in the first 150 s**.** Raw exhaust NO_X emissions were slightly reduced after 200 s from cold start. **Yang H.H. et al.2012 [13]** studied the effects of ethanol-blended gasoline on emissions of regulated air pollutant and carbonyls from motorcycles. In addition, durability testing was performed on two brand-new motorcycles of the same model, using E3 in one and E0 in the other, to assess the effects of E3 usage on motorcycle emissions. The results show that average emission factors of CO and THC decreased by 20.0% and 5.27%, respectively, using E3 fuel. However, NO_x and CO_2 emission increased by 5.22% and 2.57%.

2. Experimental Apparatus and Procedure

Exhaust gas analysis of a variable compression ratio spark ignition engine is tested. The engine is operated with bioethanol-blended gasoline. The blending was done on energy basis .Different blending ratios are to be tested .No engine modification is made. The objective is to assess whether low emissions can be achieved relatively or not.

2-1 Test Engine and Instrumentation

The experiments were performed on a research engine, which was modified from a variable compression ratio (varicomp), single cylinder; dual fuel petrol /diesel, manufactured by prodit company is used for this purpose. The specifications of the engine are shown in Table 1.

Table 1: Engine specifications. [52]

Manufacture:	Prodite s.a.s.
Cycle	Otto or Diesel four stroke
Diameter	90 mm
Stroke	85 mm
Swept volume	541 mm3
Compression ratio	4- 17.5
Max. Power output	4kW at 2800r.p.m.
Max. torque	28 N.m at 1600r.p.m.
Cooling type	Water cooled
No load speed range	500-3600 r.p.m.
Load speed range	1200-3600 r.p.m

2.2. Test fuel

The emission parameters of bioethanol-blended gasoline (E5, E10 and E15) are to be evaluated and compared with that of neat gasoline fuel (E0). The fuel blends are prepared just before starting of the experiment to provide homogenous fuel mixture.

2.3. Experimental procedures

Tests are carried out at three different engine speeds ranging from 1200 rpm to 2000 rpm; by 400-rpm increments at various loads starting from no load to 14 N.m. and at four different compression ratios (7:1, 8:1, 10:1 and 11:1). At each of these engine speeds, four different fuels are used which neat unleaded gasoline (E0) and three bioethanol blended gasoline namely (E5, E10, and E15).The letter E refers to bioethanol while the followed number refers to the percentage of bioethanol in the blended fuel . Properties of biothanol and gasoline are shown in Table 2. The purity ratio of bioethanol is 99.9% [**14**]. For each experiment, the engine is allowed to reach a stable condition and then the measurements are recorded. The total energy input value (ethanol + gasoline) is fixed. The ethanol-supplemented ratio (by energy) is defined as follows: [15]

$$EER = \frac{EE}{PGE + EE} \times 100\% \ \ldots\ldots\ (1)$$

EE … Ethanol energy

EER … Ethanol energy ratio

Table 2: Test fuel properties.

Properties	Gasoline	Ethanol
Chemical formula	CnH1.87n	C2H5OH
Molecular Weight (kg/kmol)	114.15	46.07
Density (kg/m3 at 20°C)	732	792
Oxygen (% wt.)	0	35
Octane number(RON)	86-94	105-108
Boiling point (°C)	25-230	78.5
Latent heat of vaporization (kJ/kg)	289	854
Auto ignition temperature (°C)	257	423
A/F ratio (by mass)	14.7	9
Lower heating value (MJ/kg)	43.8	26.7
Flash point	-43	9

3. Results and Discussion

In this section, the experimental results of the effect of bioethanol addition to gasoline fuel on the emission pollutants of a spark ignition engine have been presented and discussed. It must be mentioned here that the ethanol blending is based on energy replacement ratio see equation (1). The experimental program is limited to a bioethanol blending ratio ranging from (0%-15%) since at higher ratios the engine does not run smoothly.

3-1 The effect of load

Carbon dioxide is product of complete combustion of fuel. When hydrocarbon burns in presence of sufficient air then it generates heat producing carbon dioxide and water vapor as final products of reaction. Normally, CO_2 emission increases with increase in load due to enhancement in combustion process as seen from fig. (1). Further presence of alcohol provides more oxygen for burning of fuel thus the emission of CO_2 increasing with increase blending ratio of alcohol. The stoichiometric air– fuel ratio of ethanol is about 2/3 that of gasoline, hence, the required amount of air for complete combustion of the blended fuel is reduced and the mixture becomes leaner. When the engine condition goes leaner, the combustion process is more complete and the concentration of CO_2 emission gets higher.

The carbon monoxide concentration shows opposite behavior as compared with carbon dioxide as shown in fig.(2).The Carbon monoxide concentration decrease as EER increase. This is because of the fact that addition of ethanol make the mixture leaner, which gives better combustion and less CO production. The formation of carbone monoxide indicates loss of power because of oxygen deficiency in combustion chamber and hence incomplete combustion.

Unburnt hydrocarbon emission decreases with increasing load and EER as shown in fig.(3), because increasing load result in stable combustion processes and faster flame speed .This is further improved by the addition of oxygenated alcohol. It provides more oxygen for the combustion process and leads to the so-called "leaning effect". Its final result is that better combustion is achieved therefore the concentration of UHC emission decreases as the ethanol content increase.

The NO_x concentration results are very complicated. The NO_x emission depends on combustion temperature, availability of oxygen and time for combustion process. The NO_x increases as the EER increase and as the load increases as shown in the fig. (4). This is due to better combustion process, leading to higher combustion temperature, which favors NO_x formation. As load on engine was increased, the NO_x emissions for all blending ratios are also increased gradually. This is due to higher combustion temperature,

3-2 The Effect of Engine Speed

The carbon dioxide concentrations increase with increasing engine speed and EER while the CO decreases. This due to larger oxidation rate of fuel carbon to CO_2 which caused by presence extra oxygen when using ethanol blending. The increase in engine speed improves engine volumetric efficiency and mixing process, leading to better combustion process .This, leads to increasing CO_2 emissions and reducing CO emissions. As shown in figs. (5&6).

However very high engine speed reduce volumetric efficiency, which deteriorate combustion process.

Unburnt hydrocarbon emission shows the same trend as CO since both are products of incomplete combustion of fuel. fig. (7).

Fig. (8) Shows that the concentration of NO_x increases with increasing engine speed and EER at constant load due to the increase in the cylinder temperature .This is due to higher temperature caused by better combustion process. The maximum level of NO_x emission is obtained at maximum speed and maximum EER which about 1010 ppm.

3-3 Effect of Engine Compression Ratio

The results show that the concentration of CO_2 decrease, fig, (9), while the concentrations of CO & UHC increase, figs. (10&11) respectively, with increasing compression ratio for all EER values. The decreasing in CO_2 concentration and the increasing in CO concentration may be due to the dissociation of CO_2 at high combustion temperature caused by increasing compression ratio and the presences of ethanol.

The increasing in UHC concentration may be caused by the increasing of crevice volume ratio caused by increasing compression ratio.

The variation of NO_X concentration is shown in fig. (12) .The figures shows that NO_X concentration decreases slightly of low compression ratio (7,8) for all values of EER while the decrease is more noticeable at higher compression ratio may be due to longer expansion stroke which gives lower temperature at higher stages of expansion stroke fig. (12).

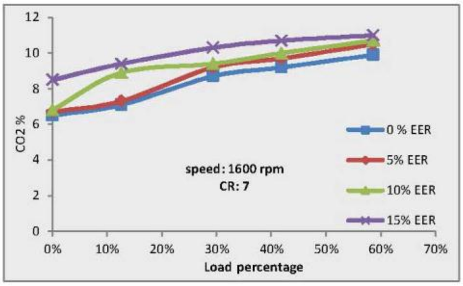

Fig. (1) Effect of load on the carbon dioxide

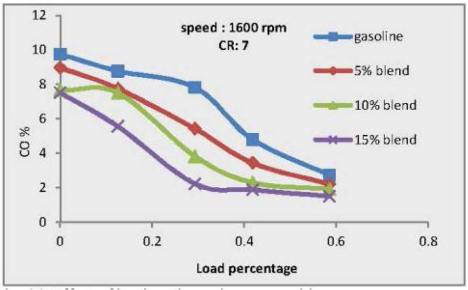

Fig. (2) Effect of load on the carbon monoxide

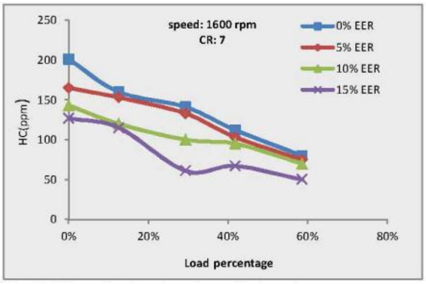

Fig. (3) Effect of load on the unburned hydrocarbon

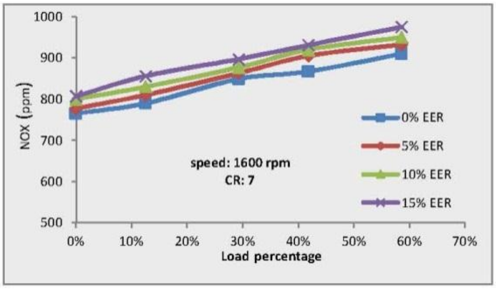

Fig (4) Effect of load on the nitrogen oxides

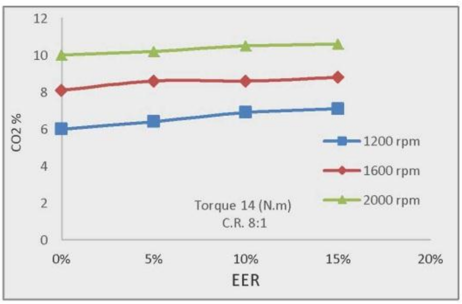

Fig (5) Effect of speed on the carbon dioxide

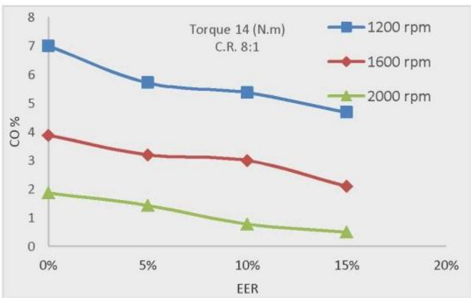

Fig (6) Effect of speed on the carbon monoxide

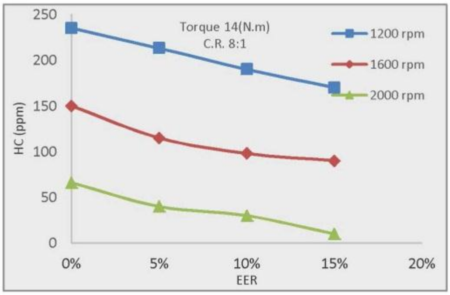

Fig (7) Effect of speed on the unburned hydrocarbon

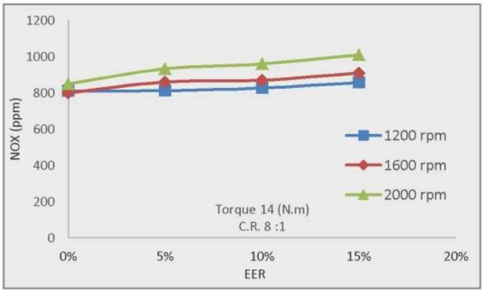

Fig (8) Effect of speed load on the nitrogen oxides

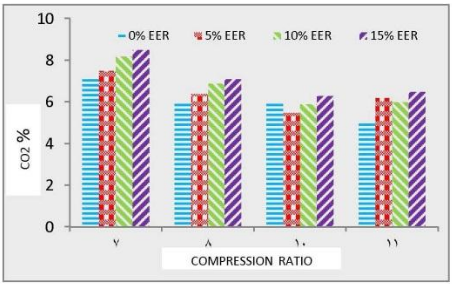

Fig (9) Effect of Compression ratio on the CO2 with different ethanol blending ratios at 1200 rpm and Load 14 N.m

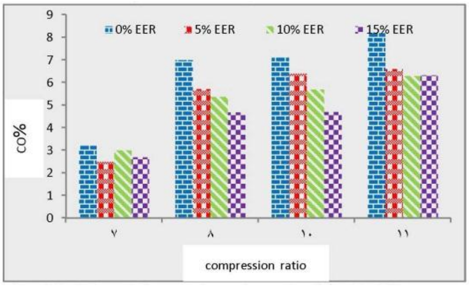

Fig (10) Effect of Compression ratio on the CO with different ethanol blending ratios at 1200 rpm and Load 14 N.m

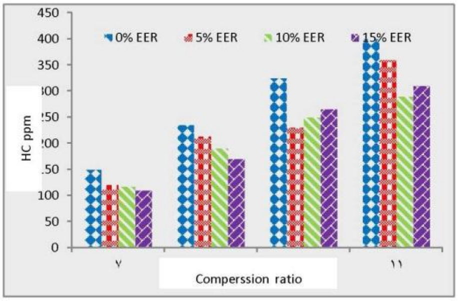

Fig (11) Effect of Compression ratio on the UHC with different ethanol blending ratios at 1200 rpm and Load 14 N.m

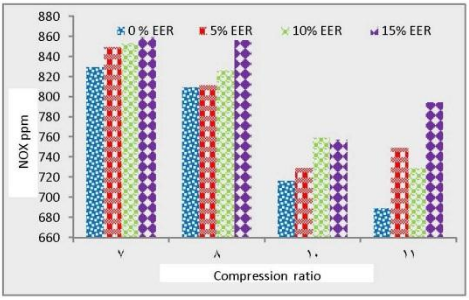

Fig (12) Effect of Compression ratio on the NOX with different ethanol blending ratios at 1200 rpm and Load 14 N.m

4. Conclusions

The main conclusions that can be drawn from the results and discussions in the previous section are as follows:

1. The concentrations of carbon dioxide and nitric oxide increase while carbon monoxide and unburned hydrocarbon concentrations decrease as EER increase.
2. Increasing engine load cause an increase in the CO_2, NO_X emissions, and a decrease of CO and UHC emissions.
3. It observed that the emission values of the CO_2 and NO_X increase while the CO and UHC decrease with increase speed of engine.
4. When increasing the compression ratio the concentration values of the CO_2 and NO_X decrease while the concentration values of the CO and UHC increase.

الخلاصة:

الكازولين وقود احفوري محدود بمستودعات ويخلف ملوثات عند حرقه. الامر الذي يدعو الى الخوض في دراسة للبحث عن وقود بديل لمكائن الاحتراق الداخلي. على مدى سنين، استخدم الايثانول البيولوجي كوقود بديل او مضاف للوقود في محركات الاحتراق الداخلي، ذلك لكون الايثانول، عند مقارنته بوقود الكازولين، يمتلك عدد اوكتان أكبر وحرارة تبخر كامنة، تسمح بنسبة ضغط اعلى وبالتالي الى كفاءة حرارية اعلى. سرعة احتراق وقود الايثانول الأعلى قد تساعد على زيادة كفاءة الاحتراق وتقليل خسائر الطاقة.

إن هذه الدراسة بحث تجريبي لدراسة تأثر إضافة الايثانول البيولوجي الى الكازولين على الأداء بدلالة (الكفاءة الحرارية المكبحية، متوسط تأثير الضغط المكبحي، واستهلاك الوقود النوعي المكبحي)، وانبعاثات العادم (ثنائي أكسيد الكاربون CO_2، احادي أكسيد الكاربون CO، الهيدروكربونات UHC وأكسيد

النتريك NO_X لمحرك الاحتراق الداخلي. تم اجراء الاختبارات التجريبية على وحد اختبار GR0306/000/037A أحادية الأسطوانة، دورات ديزل/بترول ثنائية ذات ضغط متغير "Varicomp" رباعية الدورة.

تم اجراء الاختبارات بسرع خانق متغيرة على مدى ١٢٠٠ الى ٢٠٠٠ دورة/دقيقة بفترات ٤٠٠ دورة/دقيقة ونسب ضغط تعادل ٧، ٨، ١٠، و١١ باستخدام كازولين نقي وخلائط ايثانول بيولوجي مع الكازولين. تم خلط الكازولين والايثانول البيولوجي على أساس ثبوت الطاقة المجهزة للمحرك وكانت نسب الخلط المستعملة هي (٥٪، ١٠٪، و١٥٪). كذلك تم تغيير عزم المحرك كالاتي (٣، ٧، ١٠، ١٤) نت.م.

ووُجد ان مزج الايثانول يُقلل تركيز احادي أكسيد الكاربون والهيدروكربونات غير المحترقة في غازات العادم، بمقدار ٤٥٪&٤٠.١٥٪ على التوالي ويُزيد انبعاثات أكاسيد النتروجين وثنائي أكسيد الكاربون في غازات العادم. بمقدار ١٦.١٨٪ & ٧.٥٪ على التوالي. وُجد أن زيادة الحمل تسبب زيادة تركيز الملوثات (NOx،CO_2) في حين ينقص (UHC،CO). إضافة الى ذلك، وُجد ان الزيادة في سرعة المحرك تسبب زيادة في (CO_2و NO_X)، وتسبب نقصان في (CO وUHC).

أخيراً، أظهرت النتائج ان زيادة نسبة الضغط تؤدي الى نقصان انبعاث (CO_2و NO_X)، في حين تزداد (CO وUHC).

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